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Dynamic Effect of Generating Sets on Suspended Building Floors

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ABSTRACT
This work investigates the dynamic effect of different sizes of power generating sets (Gen-set) popularly used in domestic and public dwellings in the country by way of analyzing and ascertaining the nature and magnitude of the dynamic force imposed on reinforced concrete plates by these power generating sets. From experimental observation and data obtained, it is shown that these are rotating or reciprocating machines as they rotate about a fixed axis hence are governed by the equation of rotational motion which yields a moment of force and turning (dynamic) force computed mathematically depending on the noise level on the Gen-set. A ratio of the turning force to the weight of the Gen-set is obtained mathematically establishing that it requires about 30 percent of the weight of a Gen-set to cause it to rotate. Furthermore a factor for safety of 2.0 is obtained to make up for the extra dynamic effects of the Gen-set on the plate statically. This amounts to a new design load ($1.4G_k + 1.6Q_k + 2.0Q_k$) incorporating dynamic effects of the Gen-set which yields results within 1 percent to 4 percent increase in area of reinforcement required of the conventional design load ($1.4G_k + 1.6Q_k$) for suspended plate which does not include any dynamic effects.

***KEYWORDS**: design load, dynamic force Gen- Set, reciprocating machine, suspended floors.*

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I. INTRODUCTION

A building is designed to withstand its dead weight, live load and wind load except in locations of natural disasters where dynamic effects resulting from such possible disasters are taken care of. The problem of Power is very common in the under developed and developing nations of the world. This has resulted in the large scale use of small scale power generating sets popularly called Generators in these parts of the world. Though the Nigerian Government has spent billions of dollars in trying to solve the problem of power generation and supply across the country, very little results have been achieved. Efforts by the Government to bring power to every parts of the nation in 1960 when the Electricity Cooperation of Nigeria (ECN) was established with the Rural Electricity Board (REB) constituted to compliment the effort of ECN. With the need to improve on service delivery the National Electric Power Authority (NEPA) replaced the ECN in the seventies and by the end of 2005 NEPA was replaced by the Power Holding Company of Nigeria (PHCN). The poor efficiency of PHCN over the years has brought about her privatization which has reached near completion. The Erratic supply of electricity in Nigeria has therefore left many Nigerians buying generating sets for the supply of Electricity.
When purchased, the generating sets are used in the immediate environment of the user i.e. placed directly on the ground Elastic foundation for those living in bungalows or ground floor of multi- storeys and suspended floors of the buildings for does not on the ground floors. These slabs are not particularly designed to carry these sets. The question posed by the situation is “what effect will the use of generating sets have on the strength of a building particularly when placed on suspended floors”? The bid to answer the question posed is what led to the experimental work, which is presented in this work.

1.1. **Design of Floors**

Generally the design load for slabs is given by the British code of practice as

- Design Load = $1.4G_k + 1.6Q_k$
- When the slab is continuous alternate spans are loaded, with factor of safety ranging from $1.0G_k$ to $1.4G_k$ and$1.0Q_k$ to $1.6Q_k$ here the worse loading combination is chosen for the purpose of design.
- The dynamic effect of machines or other working equipment that will be placed on the floors of building need to be given attention while designing for areas where power is epileptic.

The generating sets we are interested in are those commonly used in homes ranging from 0.6KVA to 6KVA and not necessarily the plant type which are usually given special considerations. Loads from these Gen-sets are due from

a) Dead load
b) Vibration
c) Noise

The Dead Load has another component while it is in operation that is hitherto unknown.

1.2 Theoretical background

If a generator set is stared and lifted up by hand three forces are observed, due to the reaction from the hand:

i. Yawing (rotational about the Z – axis)
ii. Rocking (about the longitudinal Y – axis) and
iii. Pitching (up and down)

With the basic assumption that a gen set is a rectangular box with sides l, b, h and the angular acceleration $\propto$ computed from data obtained, these 3 forces are computed.

II. METHODOLOGY

The following sequence of activities was carried out to realize the objective of this work.

[1] 10 number each of 3 – Different sizes of power generating sets are weighed on a spring balance mounted on a chain block stand via a purpose designed rotor.
[2] Under working condition they are also weighed
[3] The number of turns made at various time intervals are recorded in working condition of the Gen-set (the set rotates while suspended and working).
[4] A confirmation test is conducted to affirm the results.
[5] The data so obtained is analyzed.
[6] Results obtained are discussed.

2.1 Experimentation

The Gen-Set used to obtain the necessary data are characterized according to their weight, size and rated power output as shown in Table 1

Table 1: Categorization of Gen-Sets. The table shows the average of ten of each category.

Category	Weight kg	Length L (m)	Breadth b (m)	Height h(m)	Power (KVA)
Type A	19	0.36	0.32	0.32	0.95
Type B	41	0.5	0.40	0.40	1.2
Type C	47.5	0.6	0.41	0.40	2.0

Table 2: Observed readings. The table shows the average of ten of each category

No. of Revolutions	Time (secs)		
	Type A	Type B	Type C
10	32	30	42
20	61	64	80
30	94	92	125
40	127	121	166
Average period Tav.	3.14 secs	3.03 secs	4.13 secs

Turning force $F_m = L\,\alpha$

From perpendicular axis theorem

$$I = {}^{m}/_{3}\left((L^2 + b^2) + (b^2 + h^2)\right)$$

Table 3: Average force to weight ratio

Type	M(kg)	$L(kgm^2)$	Fm (Nm)	Force (N)	$F_{T/W}$
A	19.0	4.24	8.48	47.11	0.25
B	41	15.58	31	127.12	0.32
C	47.5	21.79	33.12	110.4	0.24

Average ratio = 0.27

2.2 Determination of factor of safety

The static effect of the Gen-set as a result of its imposed static load is known to have a value of 1. Considering the dynamic effect, an additional effect is calculated as 0.27.
Therefore a total effect $LL_{T.L}$ is obtained

$$LL_{T.L} = 1.0\ LL_{D.L} + 0.27LL_{D.L} = 1.27LL_{D.L}$$

A partial factor of safety γʃ for live load is already known as 1.6 without dynamic consideration. Taking into consideration the dynamic effect of a power Gen-set as

1.6 Total live load $= \gamma ʃ Q_k$
$= 1.6 \times 1.27LL_{D.L}$
$= 2.03\ Q_k$

Thus:
New factor γʃ is given as approximately 2.0

2.3 Other effects

The effect of pitching and rocking cancels out from the experimentation, the working Gen-set increases and reduces its weight $\pm$ 2kg (up and down movement). The rocking (left and right movement) was not measured. However, serviceability criteria may not be achieved as the user of the building cannot be comfortable.

2.4 Calculation of natural frequency

The following need to be considered in computing the natural frequency of a plate

- Resonance should be completely avoided. Here the frequency of the plate should be computed and compared to that of the working Gen-set.
- Where more than one Gen-set is in use on a particular floor, then the sum effect should be computed and compared using $1/F^2 = 1/f_1^2 + 1/f_2^2$---------- $+ 1/f_n^2$
- Generally Dynamic frequency = 2 times operating frequency

III. APPLICATION

A floor slab measuring 3.6m x 3.6m and 0.15m thick of a building carries a generating set of either 19kg, 41Kg or 48Kg weight and working frequency of 50HZ, Design this slab and check if it is safe against vibration.

3.1 Static analysis

Conventional factor method $1.4G_k + 1.6Q_k$
yielded area of reinforcement As = 147.62mm^2/m
Using the proposed method $1.4G_k + 1.6Q_k + 2.00Q_{KG}$,
An extra area of reinforcement will be required to sustain the extra respective moments of 0.342KNm, 0.734KNm and 0.864KNm for the 19Kg, 41Kg and 48Kg gen-set. This was obtained assuming the Gen-sets act as patch load in the centre of the suspended floor.

3.2 Vibration analysis

Using the SMR – SHM method, the dynamic frequency f_n
$f_n = 41H_z$
Frequency ratio $= \frac{2 \times 50}{41} = 2.44 > 2.0$
it is OK

IV. CONCLUSION AND RECOMMENDATIONS

- Gen-set placed on a suspended floor induces a turning force of about 30% of its dead weight.
- The factor of safety so derived from the study gives a result within 1% to 4% increase in area of reinforcement required this may reach 10% increase if heavier gen-sets are used or even multiple gen-sets are used on the same suspended floor panel.
- The effect shown above explains the reason why suspended reinforced concrete floors on which gen-set are placed have not recorded any failure or collapse, even though they are not designed to carry them. However, serviceability criteria may not be satisfied as the pitching and rocking effects which may cause some damaging effect were not studied.
- The noise level of a Gen-set influences the magnitude of dynamic load it imposes on the floor of buildings.

4.1 Recommendations

- A new design load(n) = $1.4G_k + 1.6Q_k + 2.0Q_{kg}$ is strongly recommended for the design of floors of buildings to carter for dynamic effects of Gen-sets that will definitely be used in floors of buildings for countries where power supply is inadequate.

Where
G_k is the dead load on the floor
Q_k is the live load on the floor
Q_{kg} is the imposed load (dead load) of the Gen-sets used.

- Experts should be made to compute the natural frequency of floors, where Gen-sets are to be placed (for already built houses) where the Gen-sets are used to confirm adequacy.

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